NATIONAL HIGH MAGNETIC FIELD LABORATORY $34,770,000
-$570,000 / -1.6%

National High Magnetic Field Laboratory
(Dollars in Millions)

FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	Change over FY 2016 Actual Amount	Percent
$35.34	-	$34.77	-0.57	-1.6%

The National High Magnetic Field Laboratory (NHMFL) is operated by Florida State University (FSU), University of Florida (UF), and Los Alamos National Laboratory (LANL). NHMFL develops and operates high magnetic field facilities that scientists and engineers use for research in condensed matter and material physics, materials science and engineering, chemistry, biology, biochemistry, neuroscience, energy, and the environment. It is the world's premier high magnetic field laboratory with a comprehensive collection of high-performing magnet systems and extensive support services. The facilities are available to all qualified scientists and engineers through a peer-reviewed proposal process. Users number about 1,500 per year, including faculty and staff at the three host institutions.

The laboratory is an internationally recognized leader in magnet design, development, and construction, including the development of new superconducting materials. Many unique magnet systems were designed, developed, and built by the Magnet Science and Technology (MS&T) Division of NHMFL. Since 2012, the laboratory has held the world's record for the highest nondestructive, pulsed magnetic field at 100.75 Tesla. The 45 Tesla hybrid magnet currently provides the highest steady-state magnetic fields in the world for user access; this world record has been held for more than a decade. Recently, NHMFL's new 36 Tesla Series-Connected Hybrid (SCH) magnet has reached its performance specification of 1 ppm stability and homogeneity, enabling the world's first nuclear magnetic resonance (NMR) spectrum at 1.5 GHz. The previous record was set at 1.0 GHz. These magnets enable scientists to gain new insights into the electronic structures of novel materials such as graphene, topological insulators, and high temperature superconductors. MS&T works with industry and other international magnet laboratories on a variety of technology projects. These include design and construction of high field magnets, component development, coil fabrication, cryogenics, system integration, and testing.

A $15.0 million award funded through the NSF Directorate for Mathematical and Physical Sciences, Division of Chemistry (MPS/CHE) enabled the purchase of a 21 Tesla magnet for the construction of a Fourier Transform Ion Cyclotron Resonance (FT-ICR) spectrometer. The FT-ICR instrument opened for user operations in October 2015. This 21 Tesla FT-ICR is unprecedented in sensitivity and selectivity, capable of analyzing chemical samples of great complexity, such as biological fluids, biofuels, and raw and weathered petroleum. The system impacts a broad array of research areas, such as chemistry, molecular biology, and earth science.

NHMFL is seeking funding renewal in FY 2018. The renewal proposal will allow the facility to continue operations, focus on transformational next generation magnet technology development, and further strengthen user support, education, training, and in-house research. The FY 2018 Budget Request is consistent with the very positive external review of the renewal proposal. Pending a recommendation to, and approval by, the National Science Board, NSF expects to fund the next cooperative agreement in FY 2018.

Total Obligations for NHMFL

(Dollars in Millions)

	FY 2016 Actual	FY 2017 (TBD)	FY 2018 Request	ESTIMATES[1] FY 2019	FY 2020	FY 2021	FY 2022	FY 2023
Operations & Maintenance (DMR)	$33.42	-	$33.04	$33.04	$33.04	$33.04	$33.04	$33.04
Operations & Maintenance (CHE)	1.92	-	1.73	1.73	1.73	1.73	1.73	1.73
Total, NHMFL	**$35.34**	**-**	**$34.77**	**$34.77**	**$34.77**	**$34.77**	**$34.77**	**$34.77**

[1] Outyear funding estimates are for planning purposes only. The current cooperative agreement ends in December 2017. NSF is reviewing a renewal proposal for FY 2018.

A potential impact of continued investment is the successful construction of a high field all-superconducting magnet that would make high magnetic fields attainable at lower operating costs than the current technology. This would open the door for many laboratories across the Nation to have access to high magnetic fields and could be transformational in many research areas, particularly when combined with other probes such as X-rays, neutrons, or terahertz radiation. A major scientific impact of NHMFL for the coming years is expected to come from research on quantum materials conducted by users using the record-setting magnets at NHMFL, building on the recent achievements at NHMFL, such as the observation of Hofstadter's butterfly and fractionally quantized states in graphene; and quantum oscillations from surface states of topological insulators. Another example of a potential breakthrough is in new imaging techniques for studying the brain. Currently, Magnetic Resonance Imaging (MRI) and functional MRI have been based on imaging proton spin density and intrinsic tissue relaxation rates. With higher magnetic field strengths, NHMFL is pushing to use other nuclei, which may result in new insights into mapping the brain and neuroscience.

NHMFL collaborates with more than 60 private sector companies as well as national laboratories. These include those supported by the Department of Energy (DOE), such as Oak Ridge National Laboratory, which hosts the Spallation Neutron Source, and Argonne National Laboratory, which hosts the Advanced Photon Source. International collaboration is strong; NHMFL delivered and commissioned a 26 Tesla series connected hybrid resistive/superconducting magnet to the Helmholtz-Zentrum Berlin (HZB), where it will be used for neutron scattering experiments. Collaborations also exist with the International Thermonuclear Experimental Reactor (ITER) in France, and national magnet labs in France, the Netherlands, Germany, and China.

NHMFL provides a unique interdisciplinary learning environment. The Center for Integrating Research and Learning (CIRL) at NHMFL conducts education and outreach activities, which include a Research Experience for Undergraduates (REU) program, summer programs for teachers, a summer camp for middle school girls, and activities to raise the scientific awareness of the general public.

Management and Oversight

- NSF Structure: NHMFL is supported by the MPS Division of Materials Research (MPS/DMR), with the DMR program director as the primary contact for most of the laboratory. The MPS Division of Chemistry (MPS/CHE) supports the Fourier Transform Ion Cyclotron Resonance (FT-ICR) Laboratory, which is overseen by a CHE program director.
- External Structure: A consortium of FSU, UF, and LANL operates NHMFL under a cooperative agreement. FSU, as the agreement signatory, is responsible for administrative and financial oversight and for ensuring that lab operations are consistent with the cooperative agreement. The principal investigator, the NHMFL director, reports to the FSU Vice President for Research. Four senior faculty members are co-principal investigators. The NHMFL director receives guidance primarily from NHMFL executive committee, NHMFL science council, and NHMFL diversity committee and recommendations from an external advisory committee and the users' executive committee.
- NSF initiated a community study through the National Research Council on opportunities in high

magnetic field research. The 2013 report *High Magnetic Field Science and Its Application in the United States*[14] was presented to the National Science Board (NSB) in May 2014. Public town halls were held at several professional meetings by both DMR and CHE. The report continues to inform future plans for investments in this area, providing several recommendations with respect to scientific priorities and new magnet developments.

- Reviews: NSF monitors annual plans and reports including user metrics and conducts monthly teleconferences with the director. NSF conducts annual external reviews, which assess the user programs, in-house research, long-term plans to contribute significant research developments both nationally and internationally, and operations, maintenance, and new facility development. Annual reviews also assess the status of education training and outreach, operations and management efficiency, and diversity plans. Recent and upcoming reviews include:
  - Renewal proposal site visit, August 29-31, 2016.
  - NSF program director site visit, November 2017.
  - Site visit review with external panel of experts, October 2018.

Renewal/Recompetition/Termination

The end date of the current award is December 31, 2017. In May 2015, the National Science Board determined that it was in the best interest of the U.S. science and engineering to renew rather than recompete the NHMFL award. A renewal proposal was submitted in May 2016 that has been reviewed by external experts and is currently under internal consideration. Pending a recommendation to, and approval by, the National Science Board, NSF expects to fund the next cooperative agreement in FY 2018.

The National High Magnetic Field Laboratory, Tallahassee, Florida site. *Credit: NHMFL*

[14] www.nap.edu/catalog/18355/high-magnetic-field-science-and-its-application-in-the-united-states